INTRODUCTION

TO THE

Manuring of Tropical Plants.

PUBLISHED BY

CHEMICAL WORKS, LATE H. & E. ALBERT,

LONDON AGENCY,

150, LEADENHALL STREET, LONDON, E.C.

VEREIN DEUTSCH-OESTERR. THOMASPHOSPHATFABRIKEN, BERLIN.

CONTENTS.

	Page.
Preface	5
Introduction	7
Nature of Manuring	9
Simple Manures	14
Nitrogenous Manures	15
Mineral Manures	20
Phosphatic Manures	20
Potash Manures	22
Lime Manures	24
Manures with many Plant Foods	24
Storage and Application of Manures	25

THE MANURING OF DIFFERENT CROPS

	Page.
Tobacco	26
Coffee	31
Tea	35
Cocoa	36
Coca	37
Sugar Cane	37
Rice	40
Maize	44
Millet	45
Sorghum	46
Vine	46
Oranges and Lemons	50
Pineapple	55
Banana	55
Manioka	57
Sweet Potato	58
Spices	58
Olive	58
Sesame	59
Earth Nut	59
Castor Oil	60
Cocoa Palm	60
Cotton	60
Jute	67
Ramie	67
Indigo	67
Safflower	68
Tables	69

PREFACE.

YEAR by year the virgin soil of the tropics is brought more and more under cultivation, and the time is not far distant when the last acres will be appropriated upon which a generation of unmanured croppings can be taken with impunity.

On the other hand there are lands which, though once richly fertile, have been exhausted by such cultivation and are now lying fallow, in spite of favourable climate. Henceforth, then, many tropical planters have to face the following problems:—Firstly.—How is it possible to render exhausted land fertile again? Secondly.—Would it not be more advantageous to prevent exhaustion of the land by regular manuring, and in the bargain obtain an increase of crop? Finally.—Where labour is dear, would it not be, by rational manuring, more profitable to maintain in good condition old arable land that is near one's property, than to take into cultivation some distant virgin soil, such as primeval forest land?

That is to say, the tropical husbandman will in future have to seriously consider and study manurial questions, and as a matter of fact, they have already become the burning questions of the day in many districts.

Nevertheless, we are at the present time badly posted in tropical manuring problems. Varied experiences in the application of the different sorts of manures are wanting, and even when they happen to be obtained, they are not always published. Frequently we are obliged to judge exclusively of the manurial requirements of many important economic plants of the tropics from the proportions of their constituents, a basis that is not always reliable. Frequently, too, cognisance is not taken of the fact that many manures may act on a crop favourably as regards quantity, but injuriously on the quality. Furthermore, the influence of the great diversity of the tropical soils and climate upon a rational manuring has not been sufficiently investigated, either from a practical or theoretical standpoint.

At the present time therefore, it is scarcely possible to write a faultless

book on the best modes of applying manures in the tropics, and the only thing available for the tropical cultivation is the investigation of a practical scheme of manuring. The present pamphlet contains such an investigation. I have watched its development and I welcome it as a thoroughly opportune, necessary and well thought out piece of work, which has taken into consideration the results hitherto obtained.

When certain quantities of manure are recommended for application in this book, it does not mean that therefore all further thought about the matter is unnecessary; they are given merely to furnish a basis for gauging quantities to those planters who are more or less unacquainted with artificial manures. Variations in soil and climate must everywhere be taken into consideration, and those who fail to grasp these points in their relation to the application of manures can never learn to manure rationally or profitably. The cultivator **draws the greatest profit from his manuring by the right application of appropriate materials to the special circumstances,** and *not by* the thoughtless employment of some manuring specific or recipe.

In this sense I recommend this book to tropical planters, as well thought out and capable of rendering great assistance, and I wish it success in its more extended circulation.

PROF. DR. F. WOHLTMANN.

BONN, 1897.

INTRODUCTION.

PLANTS, like animals, are living things that breathe and require nourishment. The materials necessary for the supply of that nourishment are very diverse, and are derived from different sources, inasmuch as, under certain conditions of temperature, moisture, and light, they are taken up from the atmosphere in the gaseous form through apertures in the green parts of the plants above ground, as well as from the soil by the roots below ground.

The nutritious materials emanating from the soil are the first to call for the attention of the planter, since they must be restored to the soil again, because from the soil alone can they be supplied. If the restoration is either not made at all, or made imperfectly, then the capital of the soil is gradually expended, that is to say, the store of nutrition in the soil is consumed. This capital, in fact, becomes less and less, when it is continually drawn upon and nothing is returned to it, and in this way the natural fertility of the soil is likewise diminished at each harvest. It is very seldom indeed that soils are encountered in which the nutritive matters are present in such proportions and in such condition as to suffice for any length of time for the normal development of economic crops, consequently, infertility is the inevitable result of insufficient restitution.

This necessary restitution is effected by manuring, and therefore manurial questions are amongst the most important that we have to face in the domain of agriculture. The vigour of the soil must be maintained at least at a minimum efficiency by manuring, and, wherever possible, should be enhanced. This must not be done in a defective manner, and therefore should not be conducted without having a keen regard to the characters of the soil, crop, &c. Otherwise there is a danger of the soil becoming gradually impoverished in one nutritive material or another, and then the restoration to the original fertile condition demands always far greater expenditure than a rational course of manuring entails; which, moreover, affords a certain and timely supplement to those nutritive materials that are originally more abundant in the soil.

The impoverishment of the soil and its consequent infertility, whether it happens after a few harvests or after several decades of uninterrupted cultivation, is mainly dependent on the original store of nutritives in the soil and in their decomposition and weathing occurring slowly or rapidly, and is not so much the result of climatic influences or situation. The tropical and sub-tropical climate aids the decomposition of the store of nutritives in the soil to a far greater extent than is the case in the temperate zones. But it is not uncommon to encounter, even in the latter, soils that have been robbed of their nutriment and become barren, by harvests having been taken year after year without sufficient restitution being made, with the object of obtaining as high returns as possible; so in the tropics such worn out soils are much more frequently met with, because the exhaustion of the soil takes place much more rapidly, when an ample restoration of the necessary plant food is not resorted to.

Such a practice was more or less pardonable when unlimited areas of virgin soil were still available, and new lands were constantly brought under cultivation; but nowadays, the practice is prohibitive. There is no longer any doubt about the fact, that farming can only very rarely be conducted with success when the natural fertility of the soil is the sole factor upon which to rely.

It is our object in the following pages to explain how the restitution of nutritive materials can best be effected, and in doing this, we base our views on the results of careful cultivations made in tropical and sub-tropical countries, which, even although they are not very great in number, are of importance in indicating the best mode of treatment required by exhausted or partially exhausted soils, and also the most advantageous way of utilising those soils that have hitherto been regarded as but slightly fertile. In due course it will be found that in rational manuring we have the most important auxiliary in bringing into activity those favourable conditions of vegetation offered us by nature in the form of soil and climate.

The Nature of Manuring.

PLANTS consist of water, of organic or combustible material, and of inorganic, mineral, or ash constituents. For example, according to an eminent authority, 1,000 lbs. of dry tobacco leaf contain about 180 lbs. of water, 680 lbs. of organic matter, and 140 lbs. of mineral constituents; whilst 1,000 lbs. of dried tea leaves contain 80 lbs. of water, 872 lbs. of organic matter, and 48 lbs. of mineral constituents.

If the produce, entirely or in part, is taken year by year from the soil, a continuous diminution of the ash constituents therein ensues; but in addition there is an impoverishment of the soil in decomposable organic matter, which results in an unavoidable deterioration of the physical properties of the soil, and the soil is no longer in a condition to yield full harvests.

FIG. I.

Evidence of this is given in Fig. I, which illustrates two cotton plants,—one unmanured, the other manured.

Consequently in practice we must always provide for an adequate restoration of certain nutritives; for therein lies the fundamental condition for the maintenance of the fertility of the soil.

It is sufficiently well known that it is not necessary for us to take into consideration all the nutritives that science has taught us to regard as constituents of plants, inasmuch as the store of some elements of the soil is so very great in proportion to the requirements of plants, that no deficiency need be anticipated for any conceivable period. Then again, most of the organic portion of plants is supplied by the atmosphere in superabundant quantities, the nitrogen alone coming into consideration; whilst of the mineral constituents, **PHOSPHORIC ACID, POTASH, and LIME** call for special attention. These constituents are, it is true, found in the soil in a form that can be assimilated by plants, but almost always only in comparatively minute proportions, so that without a regular addition of them to the soil, that is, without rational manuring, profitable cultivation cannot, generally speaking, be contemplated. Scarcely a single cultivated soil can be found that contains sufficient of these three constituents to fully sustain plant life, and even those fields regularly manured with dung will repay for a manuring with phosphoric acid and, under some circumstances, for dressings of potash and nitrogen, as they yield higher harvests than without such additions.

This holds good universally and for all cultivated plants, for the fundamental conditions of vegetation are always and everywhere the same; it is just the same whether we cultivate plants in the temperate or in the torrid zone. The enormous diversity of plant life which we regard with wonder and admiration, when contemplated from the material point of view, is not the result of variations in soil, nor of diversity of the constituents, but solely and simply of mode and manner of the grouping of the constituents. Under exactly the same conditions of vegetation one plant forms starch, another sugar, a third poison, &c., &c., from the same food material.

As already suggested, of all the universal nutritives, **phosphoric acid** is that which is chiefly wanting in all cultivated soils, being present in such small quantities, that are always insufficient for an abundant production of plant material; it is, however, required by every plant in considerable quantity, and always occupies one of the most prominent positions in the relative proportions by weight of the ash constituents.

Frequently **potash** and **lime,** and occasionally even **magnesia,** are present in comparatively small quantity only, insufficient for the purpose already set forth, and call for supplementing.

As regards nitrogenous compounds of the soil, so far as they are useful to plants, it is sufficient to remark that well-known facts indicate that the quantity is on an average small, whereas the requirement of combined nitrogen by all cultivated plants is fairly considerable. Nitrogen, like the other organic constituents, can be derived from the atmosphere, but indirectly; some plants, the great family of leguminosæ, such as beans, peas, clover, &c., acquire nitrogen in unlimited quantities from the air. The cultivation of these nitrogen-collecting plants furnishes an excellent means of increasing the nitrogen of the soil and raising its fertility almost free of cost.

Humus is of considerable importance to plants, not as a food but in an indirect way. It is the product of decaying plants in the soil, and acts upon and decomposes the soil constituents, as well as raising the moisture and absorptive power of the soil. In soils rich in humus, mineral manures act far more favourably on vegetation than in a soil deficient in humus. The value of farmyard manure and of green manuring is in part to be attributed to this action.

From what has been so far discussed, we may conclude that the yield of plants is influenced always and everywhere by the combined action of all the plant foods present in the soil; the more correct the proportions are, the less will the production of the plant cost, and so much the less will be the amount of materials remaining unused. From this it may be asserted that the element of nutrition most wanting in the soil controls the magnitude of the harvest; that is to say, so long as any one food material is not present in sufficient quantity, the other food materials, even when present in the soil in abundance, are of comparatively no value, and the plant suffers enormously.

Fig. II. furnishes striking evidence of the unalterable *regime* of this law. Various unequally developed wheat plants are shown, and this striking difference is solely the result of the absence of one or various plant foods, all other conditions being exactly the same.

Nowadays, when wages are increasing progressively, new holdings entail great outlays, therefore it behoves every planter to maintain his fields in good cultivation, and to obtain increasing yields from them. This is possible only by careful observation of the teaching of the new method of manuring, by the application of which the planter can so

provide that his crops want for nothing during the whole period of their development. Nevertheless, in doing this, he must take into account the financial side as well as the chemical and physiological considerations, for the manuring must be made to pay its way.

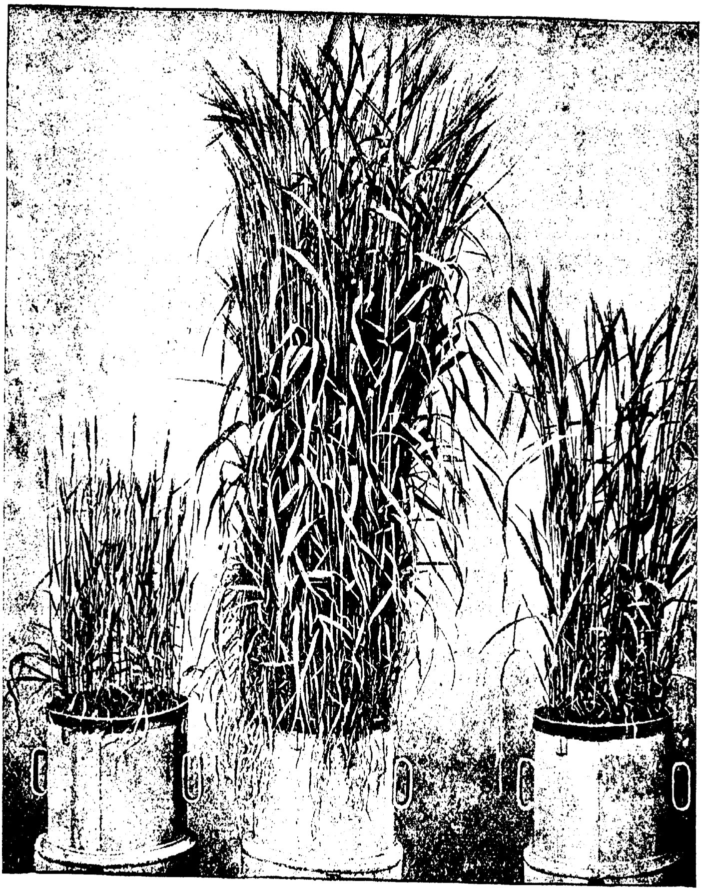


FIG. II. (see page 11.)

Not manured. Completely manured. Incompletely manured.

Evidently efforts must generally be directed to obtaining maximum harvests of all those crops that are the most remunerative when grown on the particular soil, and under the particular climatic conditions. For this purpose farmyard manure and compost are available to a less extent in the

tropics than in the temperate zones, not alone because stock-keeping is smaller, but also because more open-air feeding is practised, with accompanying loss of the manure; hence the pressing requirements of the plants for food cannot be sufficiently satisfied, and soil exhausting cultivation is adopted, with the result that impoverished fields yield bad harvests.

When this position is reached, the planter's receipts from agriculture are soon at an end. From nothing, nothing is obtained, and he who does not abundantly supply his fields with nutrition must not calculate on good harvests.

It is well known that a strong, healthy horse, which is properly fed, can bear temporary privations and unfavourable external influences much better than a badly fed and feebly nourished animal. And so is it with plants also: if they find in sufficient quantity suitable materials required for their food and development, then they will grow strong, readily overcome injurious influences, and produce abundant crops.

Simple Manures.

AS we have seen so far, the yield from the land, all the world over, is in direct proportion to the quantity and condition of the plant-food materials supplied to the soil in the form of manure. Farmyard manure and composts made from animal, vegetable, and other matters, it is true, contain all the plant food materials that should be supplied to the soil, but they are not in the right proportions. Moreover, even abundant manuring with farmyard manure, and the most careful utilization of all the waste of a farm for the preparation of compost, cannot furnish our soils with as much nutriment as they require to produce plentiful harvests. In tropical and sub-tropical regions, however, a minimum amount of farmyard manure is obtained, and the preparation of a sufficient amount of compost is only an exceptional possibility, hence it is that recourse to artificial means is all the more urgent, the rational employment of which offers the planter the following advantages :—He can, at any time, apply just those plant nutrients that are wanting, in a readily soluble and therefore quick acting form. An important point about this is that, when he likes, he can buy each of the different plant nutrients separately in quantities to suit his particular requirements. If, for example, a soil is deficient in phosphoric acid, but contains abundant supplies of nitrogen and potash, he can set matters right by the simple use of manurial materials containing phosphoric acid. The concentration of the food materials in certain artificial manures is, however, a factor that should be taken into account, so that the cost of carriage may become only a small item in proportion to the value. A hundredweight of Thomas' Phosphate Powder contains as much phosphoric acid as 70 to 75 cwts. of farmyard manure, and 1 cwt. of Sulphate of Ammonia as much nitrogen as about 40 cwts. of farmyard manure. Thus, by the use of artificial manures, not only is the cost of transport lightened, but the application is much simplified and the cost reduced.

Further, if we calculate, that for this very reason their use for the tropics is exceptionally significant, then everything would be in favour of the most extended use of artificial manures. And it is a fact, that plants in the tropics use the nutrients in the manures more rapidly and more copiously than is the case in temperate climates, and consequently the improvement of the harvest, both as regards quantity and quality, costs more for these materials in the tropics than it does for the field produce of most European countries.

With regard to the plant nutrients to be taken into consideration agriculturally for applying to the soil, there are met with in the manure market those that contain nitrogen, phosphoric acid, potash, and lime, and manures that contain mixtures of them. The principal thing always is to select the artificial manure to suit every particular soil; to apply it at the right time and in the most appropriate manner; then much better harvests will be obtained.

1. RICH NITROGENOUS MANURES.

Nitrogen constitutes the forcing power of the soil. It increases the energy of growth and causes a strong formation of leaf, haulm, and stem organs, furnishing therefore the foundation for an abundant burden of fruit crops.

According to present experience the amount of nitrogen in the soil in the tropics has not quite such a significance as it has in more temperate climates, because more nitrogen is contributed from the atmosphere to the soil of the tropics than is elsewhere the case. Nevertheless, nitrogenous manuring cannot always be neglected even in the tropics; it can, however, generally be carried out on a smaller scale than is done in the temperate zone.

Nitrogen occurs in inexhaustible quantities in the air as a free gaseous substance; we should regard this source of nitrogen as unimportant were it not that certain plants have the power of appropriating the nitrogen of the air under certain conditions. For this reason these plants are designated nitrogen accumulators. When cultivated for this purpose they provide for us an excellent means of rendering useful a cheap and constant source of nitrogen.

This power of utilizing the free nitrogen of the air for the formation of their tissue is possessed by the papilionaceous plants, such as podbearers and clovers, so long as there are present in the soil certain bacteria

that enter into a state of existence with the plant that is known as "symbiosis." Under these circumstances small nodules form on the roots of the plants, and these nodules form the medium of this acquisition of the nitrogen from the atmospheric air by the plant. The plant, however, can only make use of such accumulated nitrogen when sufficient phosphoric acid, potash, and lime are provided by the soil; but nitrogen compounds, such as nitrates, are not required. The assimilated nitrogen, along with phosphoric acid, serves for the formation of that substance most important to life—albumen. Green manuring, moreover, provides the soil with the necessary proportion of humus as well as with nitrogen. The tropical air being periodically saturated with water vapour is conducive, as is known, to the rapid decomposition of all organic substances. The experienced planter, therefore, will welcome with joy any means that will effect an increase in the quantity of humus in the soil. Furthermore, the protection afforded to the soil by the covering of the green crop is also a favourable factor; the soil is more moist under the shade of the plants, is protected from the sun's direct rays and has a more equable temperature, all conditions conducive to the activity of the bacteria in the surface soil that effect the decomposing and fermenting processes, and so help to produce that state of the soil known as good agricultural condition.

Green manuring is most beneficial on light, sandy soils, where the decomposition and consumption of the store of humus takes place with special rapidity.

The crop for green manuring is most appropriately sown at the beginning of the wet season, and the ploughing or harrowing in is done six to eight weeks afterwards, according to the state of development. Soja bean, cow peas (Dolychos), earth nut, indigo, purple clover, red clover, &c., may be cited as most suitable plants for the purpose in the tropics.

As already stated, abundant manuring with phosphoric acid, and, in most cases potash as well, is necessary to enable the green crop to develop vigorously and accumulate an increased quantity of nitrogen. The most suitable phosphatic manure is Thomas' Phosphate Powder with its high percentage of phosphoric acid and lime, whilst the potash may be most effectively applied as chloride or sulphate of potash. In Germany, the native land of the potash salts, kainite is by preference used with the Thomas' Phosphate Powder. But in the tropics, a pound of potash in kainite is considerably dearer than in the concentrated potash salts, on account of the cost of carriage, which is why we recommend the latter. The amount of the dressings to be applied scarcely permits

of being accurately fixed; but on sandy soils about 400 to 600 lbs. of Thomas' Phosphate Powder and 150 to 200 lbs. of chloride of potash per acre are about the quantities required; whereas for heavy soils, the chloride of potash should be reduced to say 75 to 100 lbs., while the Thomas' Phosphate Powder ought to be increased to 500 to 750 lbs. per acre.

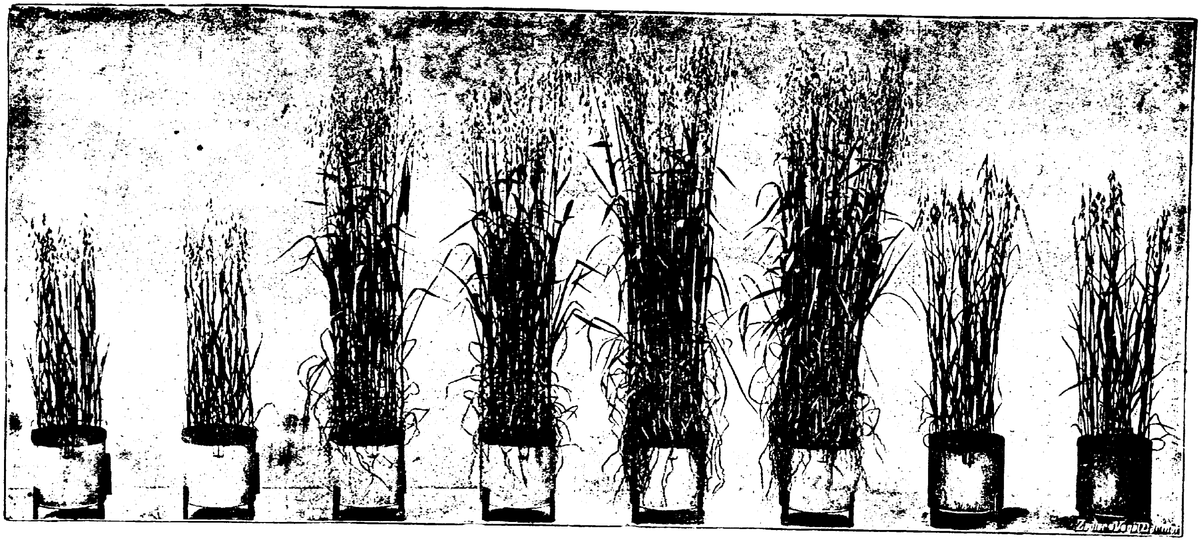
Fig. III. shows us the action of potash and phosphoric acid manuring on peas, and the inactivity of nitrogenous manuring.

FIG. III.

Not manured. Manured with potash and phosphoric acid. Manured with potash, phosphoric acid and nitrogen.

Fig. IV. illustrates the effect of green manuring on the succeeding crop and, moreover, the special superiority of the leguminous plants —lupins and peas—over the non-leguminous plant—buck-wheat—as green manure crops.

Oats grown with potash and phosphatic manure without nitrogenous dressing, on soil green-manured the previous autumn, as indicated below.



With buckwheat. With lupins. With peas. Without green manuring.

FIG. IV. (see page 17.)

In the tropics, where the conditions exist for the rapid decomposition of all organic matter, many organic nitrogenous manures have a much greater significance than they have in more temperate climates. Blood, flesh, bone-meal, &c., are examples of these, also oil cakes, and the refuse from the pressing of oil seeds, in so far as they are not of greater value for feeding purposes. For example, from castor oil seed a large quantity of oil cake is obtained which is unsuitable for feeding purposes, and therefore in the form of meal is used for manuring. Moreover, other such residues are employed to the best effect in this manner, such as those from sesame seed, olives, cotton seed, soja bean, and earth nut, &c.

The proportion of nitrogen in these substances is liable to considerable variations (see Table, page 70), nevertheless, they must be regarded as nitrogenous manures, because their proportion of phosphoric acid is insignificant.

These materials contain nitrogen in organic combination, therefore some time must elapse for their decomposition and conversion into a form assimilable by plants, such as ammonia and nitric acid. This period is indeed very short in the tropics, yet the decomposition itself goes on gradually even under the favourable conditions in those regions. For this reason those materials containing nitrogen in organic combination are just those that furnish a steady flowing source of nitrogen for plants, that continues throughout the whole period of vegetation. This adds to their value for crops of more lengthened periods of growth, such as sugar cane, coffee, tea, &c.

However, the nitrogen accumulating green-manure crops, and the nitrogenous residues from oil factories are supplemented by two other manuring materials, that place us in a position of supplying the plant, at any time, with a dressing of readily soluble nitrogen. Sulphate of ammonia and nitrate of soda are the substances referred to.

If we pour a solution of sulphate of ammonia on one of two flower-pots full of soil, and a solution of nitrate of soda on the other, both until the water flows out below, we find the ammonia remains in the soil, whereas the nitrate remains in solution, and flows out with the water. Soil, therefore, has the property of retaining the ammonia, but not the nitric acid. Consequently when we spread sulphate of ammonia on our soil there is less imminent danger of our nitrogen being washed away, which, however, is always to be feared with nitrate of soda, as it is not held back either by chemical or physical affinities, and is not prevented

from sinking into the lower layers of the soil out of the reach of the roots of plants. This is more to be observed in the tropics, where frequently much heavy rain falls and washes out the soil.

Ammonia, the compound of nitrogen with hydrogen, must undergo in the soil a change into a combination of nitric acid. This change always takes place in the area of oxidation, that is in the surface soil, and indeed in the tropics is very speedy, so that in its direct action, ammonia is scarcely behind nitrate of soda, although as regards sustained action it far surpasses the nitrate.

2. MINERAL MANURES.

In all countries, advanced agriculturists recognise as beneficial in high farming, the maintenance of an excess of mineral nutrients in the soil, and this may more particularly be done without hesitation; because the constituents in question become fixed and do not suffer loss in the soil.

If we now remember that in tropical districts, in spite of the very great diversity of soils, there are in general far more soils deficient in lime and phosphoric acid, and even in potash, than are encountered in the temperate zone, then we must at once be convinced that it behoves every circumspect planter not only to restore the extracted nutrients to the soil, but also to place an excess of the necessary substances at the disposal of his crops, for then only will the favourable conditions for vegetation of the tropical and sub-tropical countries come fully into play.

(*a.*) PHOSPHATIC MANURES.

A fundamental practice, in all farming enterprises where increased profit is desired, is the enrichment of the soil in phosphoric acid in a condition assimilable by plants. In by far the greater number of farming undertakings the harvest results are exactly in proportion to the quantity of phosphoric acid that is applied to the soil, and this application is now readily and cheaply effected, owing to the discoveries of rich sources of phosphoric acid.

The best phosphatic manures are Thomas' Phosphate Powder and Superphosphate. Bone meal, the pioneer of artificial manures, has now been placed in the background in competition with the more active forms, and in experiment all other phosphates have yielded no results, or results that have shown raw or prepared phosphate powder to be

inactive, even when used in large quantities. For these reasons we limit ourselves here to some remarks concerning the composition and action of the first two.

(1.) SUPERPHOSPHATE.—When about the middle of this century, Liebig's teachings in reference to the value of the extension of mineral and especially phosphatic manures were promulgated, experience was soon gained to show that the then available supplies of phosphatic manure, of which bone preparations were in the first rank, rarely came up to expectations as regarded their action. Then Liebig further pointed out that by treatment with sulphuric acid, the materials containing phosphoric acid had their active portions, that is, the phosphate of lime rendered more readily soluble, and thereby more accessible for the roots of plants.

This discovery may be regarded as being the first impulse towards the enormous development the manufacture of artificial manures has since experienced, as well as the reformation that agriculture has undergone through the introduction of high farming, by means of provision against exhaustion of arable land.

The value of superphosphate depends on the proportion of phosphoric acid it contains, soluble in water,—other constituents do not come into consideration. In commerce superphosphates are met with containing from 12 to 21 per cent. of water soluble phosphoric acid, and also double superphosphate, which is prepared by the use of phosphoric instead of sulphuric acid for the decomposing or dissolving operation. For this reason double superphosphate has a much greater proportion of soluble phosphoric acid than ordinary superphosphate, in fact amounting to 40 to 47 per cent. or more.

The superiority of the phosphoric acid in superphosphate over most other forms of phosphoric acid is principally due to the uniformity of its distribution. It is only equalled in activity by the citrate soluble phosphoric acid in Thomas' Phosphate Powder.

(2.) THOMAS' PHOSPHATE POWDER is a bye-product in the manufacture of steel free from phosphorus. Almost all iron ores contain some proportion of phosphoric acid, which, during the smelting of the iron stone with carbon in the blast furnace, is reduced to phosphorus, and enters into combination with the iron, yielding what is known as phosphatic pig. When this contains much phosphorus it is unsuitable for the manufacture of wrought iron or steel, as such metal would fracture when worked at the ordinary temperatures; it would be coldshort.

Thomas and Gilchrist succeeded in discovering a process by which, by the addition of lime, the iron was completely dephosphorised. The phosphate of lime obtained in this operation is called Thomas' Phosphate, in which the proportion of phosphoric acid—the most valuable constituent to agriculture—varies with the character of the pig iron, with the amount of lime used, and with the conduct of the operation. The average hitherto found in Thomas' Phosphate is 17·50 per cent. of phosphoric acid, 49·6 per cent. of lime, and 4·7 per cent. of magnesia. Finely pulverised Thomas' Phosphate is an excellent manure, at once available for use by the plant, and, as has been established by the results of experiments of unquestionable reliability, exerting everywhere a beneficial influence on the thriving and quality of all vegetation. It is true the phosphoric acid in this case is not soluble in water, but it is yet in such an active form, that we must express it as soil-soluble, that is to say, it is not only attacked by the acid juices of the plant roots, but it is also dissolved by the impregnated water of the soil and so conveyed to the roots.

Soil-soluble phosphoric acid is generally designated citrate soluble phosphoric acid, and is equal in activity to the water soluble superphosphate. By this is meant that part of the phosphoric acid in Thomas' Phosphate which is soluble in a solution of citrate of ammonia that contains a small quantity of free citric acid.

For localities, the colonies for instance, where the rainfall is great and the soils clayey and ferruginous, but deficient in lime, Thomas' Phosphate Powder is undoubtedly the best phosphatic manure; particularly as there is besides the quick, active phosphoric acid, also some less soluble phosphoric acid, which, however, after the lapse of some further time likewise comes into action, a circumstance that is of importance in the case of perennial plants in tropical climates. The phosphoric acid of super and double superphosphate runs the danger of retrogressing in the clayey and ferruginous tropical soils, and thereby becoming impaired in activity.

A further favourable action—specially observable in soils deficient in lime—is obtained by the use of Thomas' Phosphate, from its high percentage of lime, 40 to 50 per cent., an advantage upon which we shall enlarge later on.

(*b*.) RICH POTASH MANURES.

The potash contained in the ashes of plants is very suitable for the

manuring of plants, but then it only comes into the market to a limited extent. The chief source of all the potash used in agriculture is the Stassfurt natural deposit, from which the following potash manures are supplied:—

(1.) CRUDE POTASH SALTS are the natural products from the mine, which are finely pulverised and furnished as carnallite, kainite, and sylvinite. They contain sulphate of potash, salts of magnesia, and common salt, in addition to chloride of potash. These salts, irrespective of the feeding value of the potash, exert an influence on the physical condition of the soil. They attract moisture from the air, and make many soils moist and cohesive, properties which are of great value in light dry soils. With delicate crops the crude salts must only be used with great precaution as manure, because, for instance, they decrease the burning power of tobacco, also the proportion of sugar in sugar cane. On the other hand the crude salts are used by preference for plants that consume plenty of salt, *e.g.* cocoanut, or where extermination of pests is desired, with cotton for instance. In this way, as compared with common salt, the crude salts offer a second advantage in the potash they contain. For use at great distances, kainite, or the still richer sylvinite, are preferable to carnallite, which is poorer in potash. But as a rule it is advisable to use the purified potash salts, which, in addition to their greater purity, contain four or five times as much potash, which is an additional advantage, because owing to high carriage rates to the tropics, it reduces the expenditure per unit of potash, which, therefore, costs less than in the crude salts.

(2.) SULPHATE SALTS, like SULPHATE OF POTASH, and SULPHATE OF POTASH AND MAGNESIA, have been approved for all crops, even those that depend especially on quality for the harvest, such as tobacco, sugar cane, tea, pineapple, and oranges.

(3.) CHLORIDE OF POTASH is applicable in all other cases, and has the advantage of furnishing potash somewhat cheaper than the sulphate does, and with an equally good effect on the quantity of the harvest. Chlorine compounds, however, not unfrequently exert a deleterious effect on germination.

(4.) CARBONATE OF POTASH AND MAGNESIA contains no chlorine or sulphuric acid, and so presents a free supply of potash that can be at once used by plants, a particular advantage when delicate cultures, or those that require plenty of potash in their early stages of development, are concerned.

(c.) LIME MANURES.

Lime manures exert a threefold activity: nourishing, chemical and physical.

As a plant food, lime plays the same important rôle all over the globe; it is indispensable everywhere, for plants demand it in no inconsiderable quantities. Nevertheless, it receives recognition, as a rule, more for its indirect than its direct action as a manure, that is for the power it exerts in furthering the chemical changes of food material in the soil, and in improving the physical properties of the soil. This latter action can, however, better be dispensed with in the tropics than in temperate climates, for under the climatic conditions of the tropics, these changes are effected without such aid, and therefore the *nutritive* value of lime is the more important property in those regions. **This want can be supplied very conveniently and thoroughly by the use of Thomas' Phosphate Powder.** In this manure we have, as already noted, 40 to 50 per cent. of lime in a fine state of subdivision, in addition to phosphoric acid and magnesia, so that the food requirements of the most assertive plant can be completely satisfied by it.

For direct lime manuring we have, too, the following materials:—

1. CAUSTIC LIME, which has been used in large quantities in Germany on heavy clay soils for a long time, whereas on light soils it is employed only in quite small quantities. In the tropics, as we have already stated, the need of lime is not so pressing, so that one would scarcely apply more than 1½ cwt. to 2 cwt. per acre.

On light soils preference should be given to the other forms of lime manure:—

2. CARBONATE OF LIME, which is present in marls in very variable quantities, the proportion varying from 10 to 85 per cent. Agriculturally the high percentage marls are to be preferred, and, according to the character of the soil, mingled with more clay or sand, as the case may be.

3. GYPSUM, or SULPHATE OF LIME. The action of this material depends on the proportion of gypsum and of fine powder; it is only slowly and slightly soluble, so does not come into action when coarsely ground. In soils deficient in lime, both the lime and sulphuric acid are effective, in other soils only the latter.

3. MANURES WITH SEVERAL NUTRIENTS.

Many manures of natural origin, such as bone meal, Peruvian guano,

and fish guano, belong to the manures that contain several nutrients, just the same as the artificial mixtures prepared in manure factories.

It must be distinctly understood that in general there is more certainty of getting what one wants when obtaining simple manures, than when ready made mixtures are purchased. Moreover, it must be specially noted that the manurial mixtures are really more expensive than when various plant foods are purchased and used alone, or when one makes the mixture oneself; this holds good even for the natural complex manures, their price being greater than their composition justifies. For example, the price of phosphoric acid and nitrogen, the plant foods furnished in Peruvian guano, is sensibly higher in that form than when they are purchased in sulphate of ammonia and in Thomas' Phosphate Powder; exactly the same holds good for bone meal. Inasmuch as the price of the nutritives in a manure is a gauge of the purchase price, no farmer should find it difficult to decide whether a mixed or complex manure is advantageous or not.

4. STORAGE AND USE OF MANURES.

All manures that are not immediately required should be stored in a dry place. They can be sown separately: Thomas' Phosphate Powder first, then kainite, and finally, the nitrogenous manure. Thomas' Phosphate Powder and kainite can also be mixed, but the mixture should only be made shortly before use, as the mass very soon becomes hard. The mixture of Thomas' Phosphate Powder, lime or ashes, with other manures, except perhaps nitrate of soda, is not admissible. Ammonia manures would lose some of their nitrogen by such treatment, and soluble phosphatic manures would have their phosphoric acid rendered insoluble.

We must always bear in mind that the special demands of the particular plant under cultivation must be taken into consideration, as well as the character and composition of the soil, when deciding on the kind and quantity of nutrients to be added. It will then be easy for us to make the preparatory arrangements under which the foods we add will come into most complete action, and consequently we come nearer and nearer to the desired aim of getting as high a return as possible.

The Manuring of Different Crops.

1. TOBACCO.

THE problem of manuring tobacco has a special significance, because not only does the tobacco plant make exceptionally great demands manurially, but also the manuring has an indisputable influence on the burning quality, the size, the pliability, the colour, in a word on the good and bad condition of the leaf. The tobacco plant has to elaborate a large quantity of organic matter in a short period, and therefore makes great demands on the soil. It is an important matter, therefore, to take care that the lower layers of the soil wherein the roots penetrate, as well as the upper layers, are alike evenly provided with the nutritive materials. Unequal distribution of the manure gives rise to uneven development, the portions manured differently would produce weaker or stronger plants that would ripen, some sooner, some later; whereas by manuring the upper layers only, there would be a certain amount of growth as long as there was sufficient moisture in those layers, but should dryness ensue then further development would be stopped, because the lower roots would find no food.

All manures must be sown early to promote the even distribution of the foods in the soil, and so to ensure as favourable an action for the manures as possible.

The tobacco plant has a high proportion of nitrogen; nevertheless, an excessive manuring with nitrogen acts unfavourably on the quality, producing a badly-burning tobacco, rich in nicotine, and also retards the maturing. House and farmyard drainage are especially detrimental to the quality. So far as farmyard manure is concerned, that from oxen is the best. A sufficient amount of humus in the soil is of great importance; this may be furnished by farmyard manure or the cultivation of a green manuring plant. Tobacco demands a soil naturally rich in nitrogen, but such a soil will not give up its nitrogen to the tobacco in too lavish

quantities, so that a further provision of the nitrogen indispensable for strong development, presents no difficulties.

The potash requirement of tobacco is also very high, from which we may assume that it will repay for a good manuring with potash. The action is exerted, both in quality and quantity, but can only be utilised to its fullest extent when a sufficient quantity of nitrogen, phosphoric acid and lime are simultaneously present. But as the good burning quality of tobacco is associated with a larger amount of potash but the smallest proportion of chlorine, all manures containing chlorine, especially salts of potash containing chlorine, must be avoided, as for example, chloride of potash, kainite, &c. The nitrate, phosphate, sulphate and carbonate compounds of potash, and potash and magnesia, should be the only ones employed. Naturally, as in all cases, the quantity of potash applied must be greater in light sandy soils, than in heavy soils which themselves contain more potash than the former. The soil most suitable for tobacco—a mild loam—is at any rate not poor in potash as a rule.

The phosphoric acid requirement of tobacco is less prominent; nevertheless, when we remember that phosphoric acid of all plant foods is most sparingly provided in the soil, there is no doubt that due consideration must be given to its restoration, more especially as the yield depends on *the combined action of all the necessary foods*, amongst which the phosphoric acid exerts an action conducive to ripening, therefore phosphoric acid must by no means be left out when manuring tobacco. For tobacco, it is scarcely necessary to say that Thomas' Phosphate Powder is to be preferred to superphosphate, which contains sulphuric acid and gypsum. Furthermore, the lime and magnesia in the Thomas' Phosphate Powder are favourable elements. The lime requirements of tobacco are considerable, and magnesia is also present in the ash in large quantities, so that an addition of these two foods must be kept well in view when manuring the tobacco plant.

With regard to the manuring operations, farmyard manure is nowhere to hand in sufficient quantity, so good results can only be obtained by the supplementary use of artificial manures. Experience up to the present shows we must acknowledge that the improvement of the tobacco harvest in quality and quantity, and the financial success of tobacco growing, depend upon the rational application of artificial manures.

Numerous analyses and systematically conducted manurial experiments serve for a guide as to the quantity of manure to be applied. The composition of the ash is subject to excessive variations, but the

analyses of 63 samples of leaves and 3 samples of stems gave an average of :—

	Leaves.	Stems.
Phosphoric Acid ...	4·70	14·20
Potash	29·10	46·60
Lime	36·10	19·10
Magnesia	7·40	0·80

Wolff gives the following mean numbers :—

	Leaves.	Stems.
Nitrogen	24·50	16·40
Phosphoric Acid ...	6·60	9·20
Potash	40·90	28·20
Lime	50·20	12·40
Magnesia	10·40	0·50

To cover the requirements of nitrogen, potash and phosphoric acid, we may make an exception and use a compound or mixed manure, that is, nitrate of potash and phosphate of potash. They contain 44 per cent. of potash, and 13·5 per cent. of nitrogen, and 38 per cent. of phosphoric acid, and 26 per cent. of potash, respectively. By their use we avoid introducing sulphuric acid into the soil, a substance that readily acts injuriously on the quality of the tobacco leaf ; moreover, the harmful chlorine compounds are also absent from these concentrated nutritive salts ; and they are further signalised by containing a very much larger proportion of the pure nutritive matters than is contained in the ordinary manures, thus involving a smaller expenditure for carriage. By the application of 267 lbs. per acre, 40 lbs. of nitrogen, 187 lbs. of potash, and 100 lbs. of phosphoric acid are put into the soil, which will be everywhere abundant for the production of a good harvest of tobacco, for even if the crop contains somewhat more nitrogen and potash than is contained in above allowance of manure, one may depend on the store of nitrogen and potash in the soil to supply the balance.

To provide for the needs of other nutritives we take 356 lbs. of Thomas' Phosphate Powder per acre, by which the soil acquires over 62 lbs. of phosphoric acid, about 170 to 178 lbs. of lime, and 10¾ to 14⅓ lbs. of magnesia.

Therefore, two manures that are easy to obtain, simple to apply, and labour saving, are capable of appropriately supplying to the soil all the nutritive substances that are required for the production of tobacco, a harvest satisfactory as regards both quality and quantity. These are **Nitrate of Potash** and **Thomas' Phosphate Powder** or Phosphate of

Potash, and we do not for a moment doubt that the rational application of these materials will fully satisfy the most sanguine anticipations.

FIG. V. (see page 30.)

Of the nitrate of potash mentioned, the larger quantity, some 178 lbs., must be applied before planting, the rest after planting, but anyhow

before topping. By this division, that is by manuring at different periods, we favour the equal expansion of all the leaves.

The nutritive matters in nitrate of potash and phosphate of potash are soluble in water, hence are at once taken up by the moisture in the soil, and placed at the disposal of the plants. The case of Thomas' Phosphate Powder is, as is well known, different, for although the plant nutritives in it are easily available they are not soluble in water; it is therefore advisable not to delay its application until the planting, but to incorporate it in the soil before that period. As for the rest, the observant farmer will soon learn the time and mode of conducting operations.

FIG. VI.

It is worth calling attention to some results of manurial experiments on the Santa Rosa plantation in Pina del Rio, Cuba, 1894, published in the pamphlet "On the Manuring of Tropical Plants," of the Verkaufs-Syndikat der Kaliwerke. In these experiments the quantity of manures per acre amounted to 76½ lbs. of phosphoric acid, 62⅓ lbs. of potash and 49 lbs. of nitrogen. The plants on the manured plots, Fig. V., surpassed those on the unmanured plots, Fig. VI., to the following extent:—

In height	... ...	40 per cent.
In length of leaf	... ...	50 ,, ,,
In width of leaf	... ...	52 ,, ,,

2. COFFEE.

Although the application of artificial manures is a comparatively recent introduction into coffee plantations, yet it has undoubtedly been established that by them the yield can be increased to double or more, the life of the regularly manured trees be considerably prolonged, and the trees themselves be rendered much more capable of resisting pests and injuries. Evidence of the exceptionally good results obtained from the rational cultivation of coffee is afforded by the examples given by Dr. Dafert in his work "Experiences in the Rational Cultivation of Coffee," published under the auspices of the Directors of the Agricultural Institute of the State of Sao Paulo, in Campinas, Brazil, from which we take the following:—

The Agricultural Institute of the State of Sao Paulo, in 1893 took over the control of an almost neglected 16-year plantation, the yield from which scarcely paid the cost of harvesting; which, however, for this reason was all the more interesting to the institute, as many millions of coffee trees in Brazil were in a similar or even worse condition. The plantation was first of all carefully cleaned and its then yielding capacity gauged, whereby in 1893-94, 5,512 trees yielded:—

	2,288 gallons of coffee berries	=	1,783 lbs. coffee beans,	
or per tree	$\frac{1}{5}$ gallon ,, ,,	=	$\frac{1}{4}$ lb. ,, ,,	

Immediately after the harvest, first of all, only the worst trees were manured with a complex manurial mixture made up of different manures, such as blood meal, castor oil seed meal, Thomas' Phosphate Powder, chloride of potash, &c., &c., and the soil was continually raked clean. In three months the plantation visibly improved, the blossoming was quite exceptionally abundant on the manured trees, and the fructification normal. The 5,512 trees yielded in 1894-95:—

	6,182 gallons coffee berries	=	9,891 lbs. coffee beans,	
or per tree	$1\frac{1}{8}$,, ,, ,,	=	$1\frac{3}{4}$,, ,, ,,	

In 1893-94 the trees yielded coffee beans of an average value of 3d. per tree, the cost being about $4\frac{4}{5}$d., hence a deficit of $1\frac{4}{5}$d.

In 1894-95 the value of the harvest per tree amounted to 16d., whilst the expenditure was about $5\frac{1}{4}$d., that is to say each tree yielded $10\frac{3}{4}$d. profit. The cost for manure per tree amounted to less than 2d.

This is only the commencement and one may reckon on doubling the harvest of the preceding year, starting with the present favourable

condition of the plantation. Equally good results have been obtained elsewhere.

Dr. James Warne, at Itapira, Brazil, has been working his farm vigorously for ten years, and, by using farmyard manure, obtained from 15,000 trees—two-thirds very old ones:—

82,500 lbs. or about $5\frac{1}{2}$ lbs. of berries per tree.

Recently artificial manures have been chiefly but not exclusively employed, in a form similar to that adopted in Campinas, but richer in nitrogen. The average harvest per tree amounted to 6 lbs.; some manured heavily with farmyard manure only yielded $26\frac{2}{5}$ lbs.; some with farmyard manure and artificial manure, 33 lbs.

For the rest we may here observe, that decayed vineyards in Germany regarded as incapable of bearing fruit have been restored to luxuriant growth and great fertility by rational manuring. By proper treatment coffee plantations should also be made to last double the time and give more abundant yields.

A. Brunner, Helyana, Sumatra, reports that by the use of artificial manures coffee seedlings were ready for planting out after six months, that is, with one or two pairs of branches, as usually produced in not less than a year.

These communications emanating from practical sources, relieve us of the responsibility of furnishing further evidence concerning the profitable character of manuring coffee, so that it only remains for us now to treat of the method. Dr. Wohltmann, Professor at Bonn, Germany, in his excellent work, "The Natural Factors of Tropical Agriculture," notifies that the food requirements in coffee cultivation are primarily phosphoric acid, then potash, and when the soil is poor in lime, also lime. Nitrogen is required in quantity in accordance with the rainfall, dew, &c., but in a form that does not act too quickly.

According to the ash analyses, potash takes the leading place as a food for the coffee plant, but when we remember that potash in general is present in the soil in far more considerable quantity than phosphoric acid, we are prepared to agree with Wohltmann in his view of the importance of the latter.

Therefore we have to provide along with indispensable humus forming substance and phosphoric acid, the nitrogen and potash, and then it is necessary at the same time to take care that the soil does not become impoverished in lime and magnesia.

With this object we apply the phosphoric acid in a form rich in lime

and magnesia, that is as Thomas' Phosphate Powder, of which 356 lbs. per acre can be given as a satisfactory quantity. In this way the soil will obtain in a 17 or 18 per cent. powder—

About $60\frac{1}{2}$—64 lbs. phosphoric acid.
,, 160—178 ,, lime.
,, 10—13 ,, magnesia.

FIG. VII. (see page 35.)

The potash requirements can be satisfied by the use of chloride or sulphate of potash. To give an idea, we should say, 89 to 134 lbs. of either salt per acre for the purpose in question.

For the supply of the nitrogen, manures of organic origin are the most suitable, such as blood meal, residues from oil works, &c., or also sulphate of ammonia. A sufficient dressing per acre would be about 134 to 178 lbs. of a blood meal containing 12 per cent. of nitrogen, or 222 to 267 lbs. of earth nut cake, or 267 lbs. of soja bean cake, or 89 lbs. of sulphate of ammonia.

Further, we will now point out what indications coffee trees, like other continuously growing vegetation, give the planter for gauging the

separate food materials. If the coffee trees have thin wood, feeble leaf development and yellow colour, dearth of nitrogen is indicated, and they must be dressed more heavily with manures rich in nitrogen. If, on the other hand, the wood development is strong, the foliage luxuriantly developed and of dark colour, then minerals are wanting, and primarily, phosphoric acid.

The remarks hitherto made refer to coffee trees in their best period

FIG. VIII. (see page 35.)

of productiveness. In new plantations the growth of the young plants is best advanced by heavy nitrogenous manuring, and at the same time to place at their disposal a store of phosphoric acid in the form of Thomas' Phosphate Powder. In this way not only will healthy trees be ensured, but also when the bearing period is reached the field will be more beneficially influenced than by heavy annual dressings of phosphoric acid.

The difference in the development between manured and unmanured

trees is exhibited in Figs. VII. and VIII. Both were planted and subsequently photographed at the same time, and they speak for themselves.

In conclusion, we comment again on the inference to be drawn from Dafert's experiments, that the presence of humus forming matter (farmyard manure, compost, &c.) in the soil by itself acts favourably, but its utilisation is considerably enhanced by association with artificial manures. Hence it is advisable to increase as much as possible the organic manures, and then to use artificial manures too. Where stock keeping is not practicable, a good substitute can be provided in green manuring.

3. TEA.

The tea shrub thrives best on mild, deep rich loamy soil in undulatory country, whereas heavy stiff clay suits it as little as light, sandy or moorland soil. Plentiful rains and dews throughout the year are beneficial to its thriving, whereas long periods of dryness, even when watering is practiced, are unfavourable.

The food requirements of the tea shrub in the first years of its growth in good soil are not great, but later manurings with potash and phosphoric acid are indispensable. Whether the nitrogen requirement has to be satisfied or not, and in what way, depends on the character of the soil. Dung, drainage, liquid manure, fish guano, and in general all strong smelling manures, are to be avoided, as they are very detrimental to the aroma of the tea. Oil cakes on the other hand have a good action, their use for young plants particularly being usual; wood ashes rich in potash and phosphoric acid exhibit a beneficial effect, and are eagerly utilized.

The ash of tea leaves contains about 35 per cent. of potash, and 15 per cent. of phosphoric acid and of lime. Therefore it is clear that a manuring with potash and phosphoric acid, with a moderate amount of nitrogen added in, should act well. The following proportional quantities appear to be worthy of recommendation:—

Lbs. per acre.	
267—311	earth nut cake,
	or
311—356	soja bean cake.
267	Thomas' Phosphate Powder (17 to 18 per cent.)
178	sulphate of potash.

Naturally, the corresponding quantities of other oil cakes can be used, or about 107 lbs. of sulphate of ammonia.

Green manuring must be mentioned here also, as by it we can considerably increase the quantity of nitrogen and humus in the soil. The tea shrub, it is true, is to be placed along with the contented class of plants, but even they require certain foods, upon the presence of which in sufficient quantity the thriving of the plant and the greatness of the harvest depends. This the farmer has to bear in mind.

4. COCOA.

The cocoa tree requires deep coherent soil that retains moisture, but must be free from stagnant water. The cocoa tree, in spite of its exceptional requirements in the way of both atmospheric and soil moisture, cannot stand stagnant water any more than any other cultivated plant. Where there is not an abundance of rain and dew artificial watering must be resorted to.

The food requirements of the cocoa tree are varied and great. It demands, in addition to a soil rich in general nutrients, principally lime, phosphoric acid, and potash, with a high percentage of iron thrown in. Nitrogen seems to be sufficiently provided for by rain, and artificial watering, so it appears from this that the nitrogen required is not very high, especially when the refuse from the fruit is returned to the soil in the form of compost.

In the ash of unshelled cocoa beans we find about 30 per cent. of potash, 25 per cent. phosphoric acid, and 8 per cent. lime. The wood of the tree contains a large quantity of lime. On this ground Thomas' Phosphate Powder is recommended before all other manures, so that the soil obtains a liberal allowance of lime besides the phosphoric acid. With 356 lbs. per acre of 18 per cent. stuff, the plantation will receive 36 lbs. of phosphoric acid, and 200 lbs. of lime, sufficient to completely cover the nutrient requirements.

Any potash salt may be used to supply the potash, inasmuch as the presence of chlorine does not derange the cocoa tree. We use 134 lbs. of chloride of potash per acre.

If we have compost at hand, made of most varied materials, we make use of it along with nitrogenous manures of organic origin, such as fish meal, oil cakes, &c., and these cover the nitrogen requirements, and to a certain extent that of other foods.

The cocoa tree does not begin to bear till about the fifth year, but we can probably shorten this period by nourishing the young plants richly and freely. In all cases, however, the yield is notably raised, and the life of the tree lengthened, where a rational system of manuring is adopted.

5. COCA.

The coca shrub, the leaves of which yield cocaine, is becoming of more importance on account of the increasing use of this drug. Up to the present, there is not much known of the food requirements of this shrub. It thrives best in a permeable sandy loam, and shows a good result for a good manurial condition. Stutzer recommends manuring experimentally in the same manner as tea, to which we refer our readers.

6. SUGAR CANE.

The conditions for most successful sugar cane cultivation are:—Plenty of atmospheric and soil moisture, especially during the first three months of vegetation, but no stagnant water; a high temperature, without abrupt changes; a deep humus, but not too heavy soil.

Then, with sugar cane, very much is attached to rational manuring, and it must always be observed that its food requirements are very considerable. Figs IX. and X. show respectively an unmanured and a manured plant. It has been found that a cane harvest takes from the soil the following amounts of material per acre :—

		Nitrogen.	Phosphoric Acid.	Potash.	Lime.
35 tons	cane ready for grinding	41 lbs.	40 lbs.	85 lbs.	17 lbs.
2 ,, $8\frac{1}{2}$ cwt.	tops and green leaves	9 ,,	5 ,,	33 ,,	5 ,,
4 ,, $4\frac{1}{2}$,,	dry leaves	23 ,,	8 ,,	53 ,,	50 ,,
41 tons 13 cwt.		73 ,,	53 ,,	171 ,,	72 ,,

It is evident that where such a large amount of food material is taken away a corresponding return must be made, if impoverishment of the soil is to be avoided, and when we inspect these numbers we can scarcely wonder that many manurial experiments hitherto made have not attained the anticipated result. Far too much nitrogen has been employed, whilst the necessary mineral constituents have been neglected, particularly phosphoric acid that is always present in the soil in only minimum quantities. The yield of cane of a necessity increases with the

quantity of nitrogen, but then at the cost of the quality, for a diminution of the amount of sugar follows. Hence Professor Stutzer exacts a plentiful dressing of readily soluble phosphoric acid and potash manure free from chlorine, but not too much nitrogen. We also, on good ground, are opposed to a too abundant nitrogenous manuring, but then we regard Stutzer's recommendation of 89 lbs. of sulphate of ammonia as somewhat too low. It would not even approximately cover the requirements of the sugar cane; probably Stutzer starts on the assumption that this nitrate of soda is only to be supplementary to the manuring with farmyard manure

FIG. IX. (see page 37.)

or compost frequently employed in sugar cane growing. In most cases double that quantity, and, in many instances, treble the amount would be required to give a satisfactory harvest, as has been established by numerous experiments conducted in Java; when, too, the fact known to every sugar cane grower was again confirmed, that phosphoric acid always neutralised the undesirable influences exerted by the heavy dressings of nitrogenous manures. The action was especially striking in one case where there was harvested—

67,166 lbs. cane	and	5,896 lbs. sugar,	without	phosphoric acid,
89,053 ,, ,,	,,	9,388 ,, ,,	with	,, ,,

As phosphatic manure, Thomas' Phosphate Powder is particularly adapted for the special reason that sugar cane requires, besides phosphoric acid, a large amount of lime in the soil. A manuring with 356 to

Fig. X. (see page 37.)

400 lbs. of Thomas' Phosphate Powder per acre will be sufficient to ensure a full harvest if the soil is not exhausted.

The most suitable material for returning the large amount of potash to the soil is only furnished by the purest potash preparation free from

chlorine, for sugar cane exhibits a great sensitiveness towards any chlorine in the soil. Experiments with kainite resulted in a considerable reduction in the amount of sugar, and increased the difficulties in the factory. Therefore, only the pure sulphate of potash can be used, and about 178 lbs. per acre should serve for an average dressing.

7. RICE.

Alessio Malinveri states that the great majority of human beings are fed on rice, therefore it must be regarded as one of the most important of our cultivated plants. As far as we are concerned only the marsh rice and mountain rice are taken into consideration. The latter makes but small demand on climate or soil, but is also of low quality.

The rational cultivation of marsh rice demands, besides high temperature, plenty of water, and in fact, such that can be regulated in the fields as desired; want of water depresses the yield very much.

The food requirements of the rice plant extend principally to phosphoric acid, then to nitrogen, yet, under certain circumstances, an application of potash is used. Green manuring is successful, according to Prof. Kellner, of Japan, where Astragalus lotoides, Lem. was used for the purpose.

Figs. XI. and XII. show us the difference between manured and unmanured rice plants.

According to a comprehensive communication from Prof. Kellner, of the University of Tokio, those plants developed best that had received nitrogen, phosphoric acid, and potash; the next being those receiving nitrogen and phosphoric acid; those without phosphoric acid being scarcely distinguishable from the unmanured; even the use of plenty of nitrogen and potash, in the absence of phosphoric acid, did not produce more than was harvested without manure.

These experiments, made to throw light on the soil store of nitrogen, phosphoric acid and potash, demonstrated that the soil was principally deficient in assimilable phosphoric acid, whilst it had an appreciable store of nitrogen and potash.

Prof. Kellner proved that the customary manuring in Japan, compared with the requirements of the rice plant, was above all much too poor in phosphoric acid; furthermore, he pointed out that throughout Japan, a great scarcity of this nutrient existed, which would have to be rectified by drawing supplies from abroad, inasmuch as there is no natural supply of phosphates in Japan.

Kellner also investigated the effect of different successive rice crops on the exhaustion of the soil, and the action of various manures in this

FIG. XI. (see page 40.)

direction; he showed that to produce 100 lbs. of unhusked rice-grain it required 2·94 lbs. of nitrogen = 14·5 lbs. of sulphate of ammonia, 1·44 lbs.

of phosphoric acid = 8 lbs. of 18 % Thomas' Phosphate Powder, and 1·5 lbs. of potash = 3 lbs. of sulphate of potash. If 4,450 lbs. of unhusked rice grain is harvested per acre, there would, therefore, be extracted from the soil—

131 lbs.	of nitrogen	= 650 lbs.	of	sulphate of ammonia.
64 ,,	,, phosphoric acid	= 356 ,,	,,	Thomas' Phosphate Powder.
67 ,,	,, potash	= 134 ,,	,,	sulphate of potash.

In practice it is never necessary to supply the soil artificially with all the nitrogen; a third or less will see one through, and only in exceptional cases need this be exceeded.

It is, however, quite a different matter with regard to phosphoric acid, the whole of this must be restored in the case of rice culture, so that 356 lbs. of Thomas' Phosphate Powder per acre must be regarded as the minimum quantity.

With regard to the potash manuring it is difficult to fix a figure; a certain amount is brought in solution by the water, or in mud, so in most cases a small dressing of potash suffices to obtain best harvests, some 44½ lbs. per acre, which may be made somewhat higher for lighter soils.

Many experiments in the plains of North Italy have confirmed this, the experiments were exhaustive, and, of course, again show that a natural manuring with nitrogen, phosphoric acid, and potash has produced the greatest harvest and also the highest profit per acre, £2 19s. 10d., after deducting the cost of manure, £2 9s. 1d.; the crop manured with phosphoric acid alone was somewhat smaller in quantity, but after deducting the cost of manure, £1 0s. 0d., left a surplus of £2 18s. 1d., whereas the crops grown without phosphoric acid did not cover the cost of the manuring.

From these experiences we are, without doubt, justified in coming to the conclusion that the financial success of rice cultivation is everywhere intimately connected with abundant phosphatic manuring; and that nitrogenous manuring must not be neglected is a matter of fact, when dealing with a graminaceous plant, like rice.

Though the cultivation of marsh rice is only possible where abundant water is available, mountain rice requires no watering, but, nevertheless, no inconsiderable amount of rain and dew is needed. As it prefers a lighter and somewhat sandy soil, the manuring must accordingly be modified, particularly as regards the potash. The potash withdrawn by the harvest from the soil must pretty nearly all be

returned in this case. Therefore, we should require about 111 to 134 lbs.

FIG. XII. (see page 40.)

of sulphate of potash per acre, having nitrogen and phosphoric acid in about the same quantities as with marsh rice.

8. MAIZE.

Maize makes a heavy claim on the composition of the soil so long as an appropriate quantity of food matter is maintained; deep sandy loam, with some humus and lime, is the most approved soil, which should be moist but not wet, a moderate degree of atmospheric moisture is also propitious.

Heavy manurings are required as a rule, as this plant has a large capacity for food stuffs. In Germany, so far as maize can at all be grown, besides heavy dressings of farmyard manure, supplementary manurings have to be employed. In the tropics, farmyard manure is

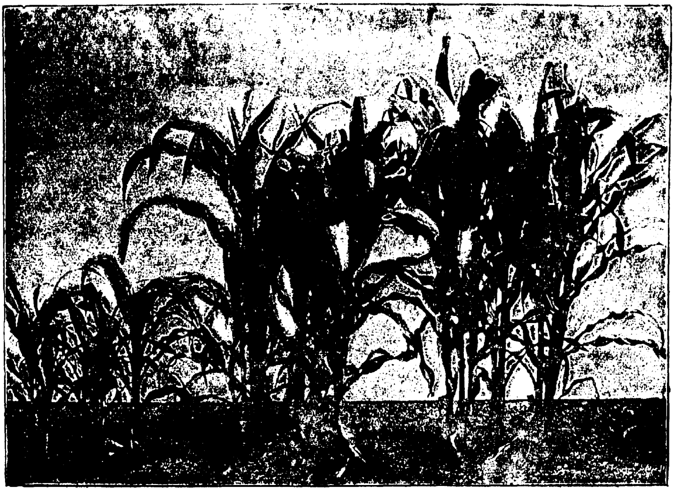


FIG. XIII. (see page 45.)

wanting, or is otherwise of high value, so that reliance has to be placed on the use of artificial manures, which, moreover, even on such soils raises the harvest of maize to a considerable extent, as has been proved by Mr. West, of Hadley, Massachussetts.

Maize, it is well-known, has great nitrogen requirements, therefore more or less nitrogenous dressings are used, which are only reduced to the minimum in very rainy districts. But in addition to nitrogen, phosphoric acid and potash have to be considered. A good harvest of 4,272 lbs. of grain and 8,010 lbs. of straw per acre, takes from the

soil about 55 lbs. of phosphoric acid, 147 lbs. of potash, and 116 lbs. of nitrogen.

The need for phosphoric acid is beneath that of nitrogen and potash, as might be assumed from the nature of the maize plant as one of the *Gramineæ*, nevertheless as the soil-phosphatic acid is not suitable to furnish the supply, such as it is, suitable phosphoric manuring is advised for maize. It is well, in good cultivation, to supply the soil with the full requirement for an abundant harvest, for which purpose about 356 lbs. of Thomas' Phosphate Powder would suffice.

Whether potash should be applied, or in what quantity, depends less on the large demand of the crop, than on the composition, strength, and manurial condition of the soil. If maize is grown on heavy land, manured with farmyard manure, then a special manuring with potash does not appear necessary; but on a light soil, with insufficient farmyard manure, the addition of potash is indispensable. Experiments have shown that in such cases, sulphate of potash has a favourable influence on the yield of both grain and straw, 134 to 160 lbs. per acre being an appropriate dressing. In experiments on manuring maize, sulphate of potash has been found to enhance the grain production, and chloride of potash the straw.

Nitrogenous manures, however, have the greatest effect in increasing the yield, as may be seen from Fig. XIII., in which there are some maize plants manured with phosphoric acid and potash, without nitrogen, and others, the stronger, manured with different quantities of nitrogen. According to the condition of the soil, the dressing of nitrogen may be from 27 to 40 lbs. per acre, to furnish which, 178 to 222 lbs. of nitrate of soda, or 134 to 178 lbs. of sulphate of ammonia is required. Under very many circumstances it is to be recommended that both these manures should be employed, using about 89 to 134 lbs. of sulphate of ammonia when sowing, and later on spreading 89 lbs. of nitrate of soda over the sprouted seed.

9. MILLET.

Heavy land does not suit millet at all, and less still wet soil; it succeeds best in a light but deep soil, in a dry place, as dryness suits it above all.

It is strange that there are no manurial experiments in connection with millet, which has been cultivated since time immemorial, and still

occupies the fourth position amongst the bread producing grains; although its importance has fallen off considerably in course of centuries. Like maize and rice, it belongs to the *Gramineæ*, and has no great absorbing power for phosphoric acid, therefore, special attention has to be paid to this when manuring; moreover, nitrogenous manuring cannot be dispensed with, but in connection therewith, due consideration must be given to the climate and the condition of the soil.

In general the quantities given for maize pass also for the manuring of millet, but then the dressing of nitrogen may be somewhat reduced to 89 to 134 lbs. of sulphate of ammonia per acre. The phosphate manuring is effected by the use of 356 lbs. of Thomas' Phosphate Powder per acre, and about a requisite potash manuring may be made by the use of 67 to 89 lbs. of sulphate of ammonia.

10. SORGHUM.

The sorghum plant is met with principally in the tropical and subtropical districts of Asia and Africa, but also in North America; like millet, it prefers a deep, dry soil. Its chief food requirement appears to be phosphoric acid; as regards the manuring in general we refer our readers to what was said in connection with millet.

11. GRAPE VINE.

The abundant experience collected in connection with the use of artificial manures in vineyards during recent years, permits us to include in our treatise this crop also, which was formerly exclusively manured with farmyard manure, liquid manure and compost, and to discuss the treatment of it without depreciating the great value of these latter manures; but we must say that they are nowhere to be obtained in sufficient quantity, and, moreover, their composition is not such as either to supply the food requirements of the vine, or to furnish in a proper manner the nutrients that fail in the soil. All the farmyard manure obtainable should be employed to improve the physical condition of the soil; but artificial manures are indispensable to establish the correct proportions of nutrients. They can, however, even be used by themselves with splendid results, as numerous testimonies from practice confirm and Figs. XIV. and XV. illustrate.

Amongst the mineral nutrients, potash occupies the most prominent

position, inasmuch as it is taken from the soil in largest quantities, amounting to 62 to 107 lbs. per acre, according to the season and the poorness or abundance of the vintage. For all that, the need for a heavier manuring with potash in vine culture is more seldom remarked than that for a regular and heavy dressing of phosphoric acid. This is due, as we know, to the composition of the soil, since potash is the chief constituent of a large number of soil-forming minerals, and, therefore, is present in considerable quantities in many soils, whereas phosphoric acid is regularly conspicuous by its absence.

We have, in the first place, Thomas' Phosphate Powder at our disposal to furnish the indispensable phosphoric acid required for the maturing of the wood and to supply the grapes. Until a few years ago superphosphate was the phosphatic manure most generally used in manuring grape vines, but now it has had to cede its place to Thomas' Phosphate Powder, in which the sustained character of the phosphoric acid, with its continuous uniformity of action, is exactly what is of great significance for the perennial vine. The manuring is opportunely effected after gathering the grapes each year. An average dressing is 356 to 445 lbs of Thomas' Phosphate Powder per acre, that should be evenly spread and hoed under.

This method serves also for the potash manuring, which is best effected by means of sulphate of potash, of which about 89 to 134 lbs. per acre should suffice. A larger dressing of 175 to 222 lbs. is only called for on light sandy soils, or in those cases where the growth of the wood and foliage of the vine is not strong enough.

This condition, moreover, indicates that there is also a deficiency of nitrogen, which must be corrected if a full harvest is to be rendered certain. Under these circumstances, we must manure simultaneously with nitrogen, phosphoric acid and potash, for it is only by the use of such complete manure that a paying harvest can be produced.

With regard to the nitrogenous manuring, it is appropriate to apply it not only in the readily soluble form of nitrate of soda and sulphate of ammonia, but also in the more gradually acting form of organic nitrogenous material. To give an idea of the working of this view, 356 lbs. of bone meal may be used per acre, to be followed later, when vegetation has started, by about 178 lbs. of nitrate of soda.

It must always be remembered that it is just the vine that requires a very abundant manuring, so that one may not be induced to commit the error of economising the manures in the wrong place.

Fig. XIV.

Unmanured, yielded 11 small bunches of grapes.

Unmanured, yielded 10 small bunches of grapes.

Manured in 1893 with oil cake and chloride of potash, and yielded 30 large bunches of grapes.

Fig. XV.

Manured in 1894 with nitrate of soda, Thomas' Phosphate Powder and chloride of potash, and yielded 22 large bunches of grapes.

VEREIN DEUTSCH-OESTERR. THOMASPHOSPHATFABRIKEN, BERLIN.

12. ORANGES AND LEMONS.

Professor Hilgard, of the University of California, has found that these fruits, oranges and lemons, remove the following quantities of materials from 1 acre of land :—

	Nitrogen.	Phosphoric Acid.	Potash.
17,800 lbs. of Oranges	33½ lbs.	9½ lbs.	37½ lbs.
17,800 lbs. of Lemons	26¾ ,,	10¾ ,,	47 ,,

These numbers, however, do not take into consideration the by no means inconsiderable amount of nutrients taken up by the wood and leaves, so that the numbers have to be increased to some extent, in order to cover the actual food requirements in orange and lemon growing. Numerical data are wanting for this total requirement, and, moreover, there is but little practical information available concerning these crops.

Dr. Woodbridge started some experiments on manuring oranges, in South California, in 1893. Each plot containing 10 orange trees received the manures indicated in the following table, which were repeated in the spring of 1894. On the 22nd of April, 1895, the harvested fruit from the different plots was analysed in the laboratory with the following results:—

No. of Plot.	Character and Quantity of manure in lbs. per acre.	Quality of the Fruit: Weight of peel.	Weight of dry in juice.	Sugar in juice.	Increase of sugar above unmanured.
1	Unmanured	40·0	7·50	8·37	—
2	20 lbs. nitrogen	39·3	9·01	10·64	27·1
3	80 ,, phosphoric acid ...	38·2	8·74	10·77	28·6
4	75 ,, potash	36·0	8·20	9·80	17·0
5	20 ,, nitrogen ... 50 ,, phosphoric acid	37·6	7·92	9·55	14·0
6	Unmanured	—	—	—	—
7	20 lbs. nitrogen ... 75 ,, potash ...	37·2	8·71	10·64	27·1
8	50 ,, phosphoric acid 75 ,, potash ...	34·0	9·33	11·38	35.9
9	20 ,, nitrogen ... 50 ,, phosphoric acid 75 ,, potash ...	31·0	9·33	11·52	37·6
10	400 ,, gypsum	—	—	—	—
11	? ,, farmyard manure	36·0	8·40	9·90	18·0

Dr. Woodbridge reports on these experiments:--"The fruit on the plots manured with farmyard manure was of lower quality, the peel was much pitted and had several soft places, and the fruit was somewhat woolly. The plot manured with nitrogen alone, gave more woolly fruit than any other. The fruit from plots 8 and 9 were of much better appearance than all the others, and had a deeper colour, especially the produce of plot 9, which was also observed in the very healthy appearance of the leaves. A particularly striking fact is, that the amount of sugar in the juice of the fruit from plot 9 is 37·6 per cent. higher than that in the unmanured fruit, whilst the proportion of peel was 22·5 per cent. less."

Unfortunately, the magnitude of the harvests in these experiments is not given, yet the conclusion is justified that the complete manuring on plot 9 has been of the greatest benefit to the quality and quantity of the fruit and to the development of the trees.

Other experiences support this view; amongst them those obtained in the cultivation and manuring of lemons in Florida.

The lemon tree illustrated in Fig. XVI. yields 8 to 10 boxes of lemons annually; it received, three years in succession, about 40 lbs. of a manurial mixture containing 4 to 5 per cent. nitrogen, 4 to 5 per cent. phosphoric acid, and 12 to 13 per cent. potash, the quantity being divided into three portions, which were spread in February, June and November respectively, in trenches, 8 to 12 inches deep, at a distance of from $\frac{3}{4}$ to 2 inches round the stem, and then doused with water, the trench being again filled up. According to reports, the manuring started with $4\frac{1}{2}$ lbs. of mixture on quite young trees, and the quantity was increased gradually until, when the trees were 8 years old, the 40 lbs. annually was reached; at this age, therefore, they received, on an average, $1\frac{3}{4}$ lbs. of nitrogen, $1\frac{3}{4}$ lbs. of phosphoric acid, and $4\frac{1}{2}$ lbs. of potash, corresponding to 9 lbs. of sulphate of ammonia, 11 lbs. of Thomas' Phosphate Powder, and 10 lbs. of chloride of potash.

At the same place similar results were obtained in orange growing, as is shown in Figs. XVII. and XVIII.

The application of the manurial mixture was the same as in the case of the lemon trees; but the composition showed a slight difference, for with the same amount of potash there was somewhat less nitrogen and somewhat more phosphoric acid:—it consisted of 3·3 per cent. nitrogen, 5 per cent. phosphoric acid, and 12 to 13 per cent. potash.

In this case also the manuring was commenced with $4\frac{1}{2}$ lbs. per

FIG. XVI. (see page 51.)

FIG. XVII. (see page 51.)

FIG. XVIII. (see page 51.)

annum on quite young trees, the quantity being increased every year. The illustrations show 6-year-old trees, at which period they received 22 lbs. of the manurial mixture.

13. PINEAPPLES.

Pineapples thrive best in a moderately heavy rich soil, with a clayey retentive subsoil. They prefer abundant moisture of both atmosphere and soil during the first half of their period of vegetation, and later hot sunshine. Of the food requirements, nitrogen is the most prominent, which may be given in heavy dressings so long as the other food materials are not forgotten.

Illustration, Fig. XIX., represents a pine field in Florida, U.S.A., dressed with a manurial mixture, which amounted to per acre 48 lbs. of nitrogen, 80 lbs. of phosphoric acid, and 35 lbs. of potash. The field was planted at the commencement of June, 1892, after receiving the dressing of manure as first set forth, the plants being 18 inches each way from one another; later on, a top dressing of poultry manure of unknown composition was applied.

The land corresponded in character to a light sandy Florida soil of low value. It had a moderate amount of humus and sand in the surface layers, and at a depth of 1 to 2 feet a solid impervious subsoil; its physical characters therefore made it suitable for pineapple cultivation. In June, 1893, 5,000 pines per acre, worth 5 cents a piece were harvested, and in June, 1894, the harvest had increased to 11,724 pines per acre, worth 10 cents a piece at first buyers' market; this in the report is recorded as a perfect result.

Farmyard manure, compost, guano, blood and fresh meal, oil cakes, Thomas' Phosphate Powder, sulphate of potash, and kainite may be used as sources of nitrogen, phosphoric acid, and potash respectively. The farmyard manure must only be supplied in a fully rotted condition, so that all the plant nutrients are as assimilable as possible.

14. BANANAS.

A deep, rich, moist loam is the soil for bananas; extremes of soil do not suit it, neither deep heavy clays, nor light sandy soils. Its food requirements are not small; the use of compost and wood ashes has a very favourable effect. Therefore large quantities of compost are recom-

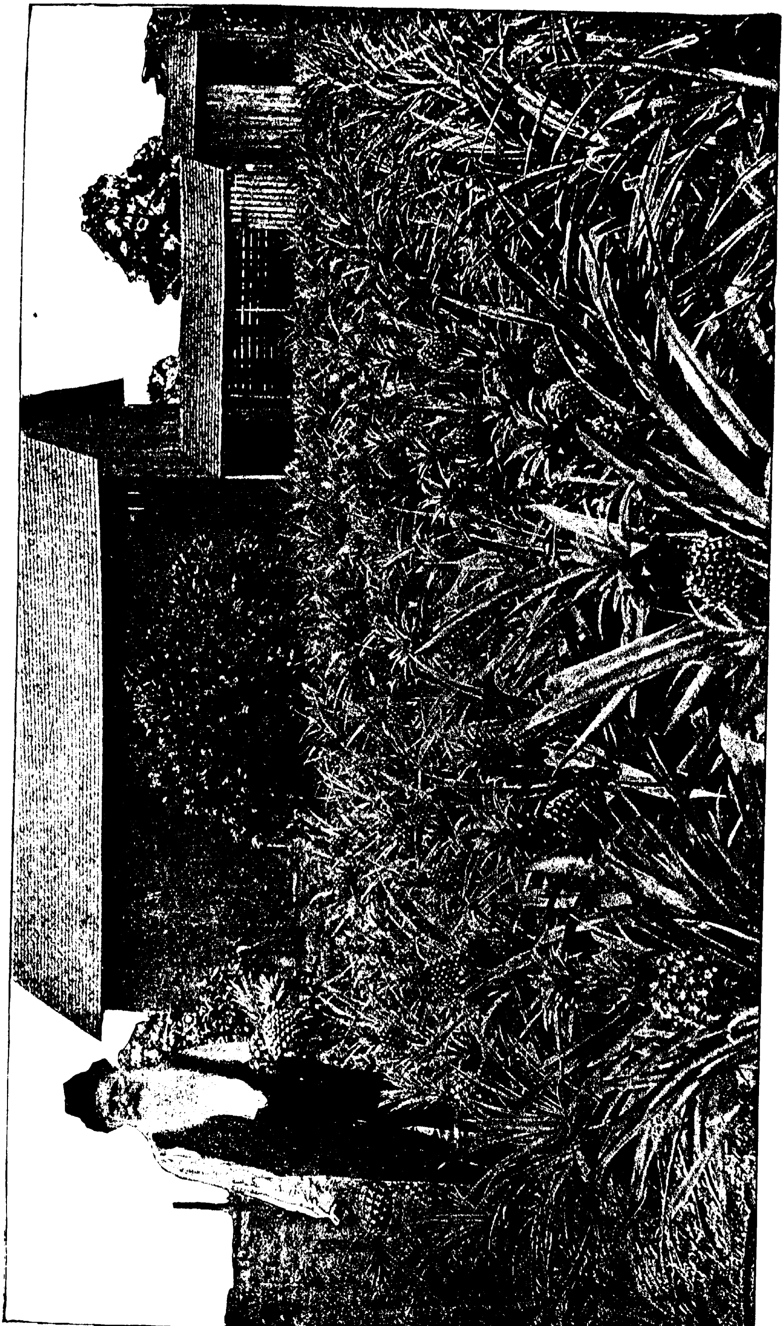


FIG. XIX. (see page 55.)

mended, in the preparation of which all sorts of refuse is employed, including the banana leaves. Kainite is appropriate for supplying the potash requirements, since both the potash and common salt it contains encourage the growth of the banana. 445 to 534 lbs. per acre may be regarded as a suitable dressing of kainite. Phosphoric acid is applied as Thomas' Phosphate Powder, 267 lbs. per acre being about sufficient. A nitrogenous manuring in addition to the abundant use of compost is scarcely desirable.

15. MANIOKA.

The plant ordinarily cultivated is the bitter manioka *(Manihot utilissima Pohl)*, the sweet manioka *(M. Aipi P.)* being less frequently encountered. The flour (Farinha) prepared from manioka serves in the tropics for making bread, and in Brazil especially in the preparation of foods. A starch preparation manufactured from it forms a well known article of export under the name of Tapioka.

The cultivation of the manioka shrub, which belongs to the family *Euphoribacæ*, repays very well, as an exceptionally large yield of starch is obtained from the area planted. The food requirements are as a consequence large, and therefore rational manuring should prove very profitable.

Amongst the requirements, potash occupies the first position, then phosphoric acid, calls for attention; and it is also well known the plant is grateful for moderate dressings of nitrogen. Sulphate of potash should be used for the potash manuring, as the salts containing chlorine reduce the amount of starch in the roots. Phosphoric acid is best applied in the form of Thomas' Phosphate Powder, and the nitrogen as organic nitrogen in the form in which it exists in blood meal, fish meal, oil cakes, and such like.

As regards the quantity of the manures to be applied per acre, the following numbers may serve as a guide:—

134	lbs. of	sulphate of potash.
267	,,	Thomas' Phosphate Powder.
178	,,	blood meal or the like.
267	,,	soja bean or nut cake.
245	,,	earth nut cake.

If farmyard manure or compost is available, its use is to be highly recommended, in which case the potash and nitrogenous manuring may be reduced one third, perhaps even a half; this depends on the quantity and quality of the farmyard manure, &c.

16. SWEET POTATO.

This plant *(Batatas edulis Choisy)*, which resembles the potato in its food requirements, is extensively cultivated in the tropics and South Europe for bread making; its fleshy masses form the staple food of the poorer classes in South America. It exhibits the best effects from a manuring with potash, than from nitrogen and phosphoric acid; at least, the manurial experiments hitherto conducted point in this direction, for the results thereof show that nitrogen and phosphoric acid are only capable of producing good harvests when a dressing of potash is also employed.

The sweet potato likes rich sandy loam, but can also stand a lighter sandy soil. The more sandy the soil, the more indispensable are average dressings of farmyard manure, the potash and phosphoric acid of which must be supplemented by the use of artificial manures.

In selecting potash salts, only the purest salts must be considered, as kainite diminishes the amount of starch and sugar in sweet potatoes. Thomas' Phosphate Powder is also useful in this case for the phosphatic manuring. As regards the quantities to be employed, we refer our readers to the numbers given for manioka.

17. SPICE CULTIVATION.

There is little reliable information concerning the manuring of the various spice plants; but it seems that any manuring pays well that comprises farmyard manure, compost, and such matter of organic origin in conjunction with mineral manures. The latter factor is more particularly important when land has been some time under cultivation, and has been furnished with a provision of humus and nitrogen, for under such circumstances even heavy dressings of Thomas' Phosphate Powder with sulphate of potash, or sulphate of potash and magnesia, will fully repay the outlay.

18. OLIVE.

The best place for the olive is an open calcareous soil, with the least possible degree of moisture; it cannot stand a wet soil. The food requirements, as is the case with other oil plants, are first in the direction of nitrogen, and good harvests are only to be obtained when

manurings are made annually. Moderately rotted farmyard manure or ploughed in green crops, or, in general, slowly acting organic manures, suit these trees best. The sowing of the green crop is done at the beginning of the rainy season, and to make the crop (beans, peas, vetches, purple clover, &c.) grow luxuriously, the following manuring per acre is used—

267 lbs. Thomas' Phosphate Powder,
,, ,, kainite.

19. SESAME.

The sesame plant thrives best in well cultivated, light calcareous land. This plant, also, chiefly demands plenty of nitrogen, and it is questionable whether—considering the shortness of the period of vegetation—nitrogen in the form of slow acting organic matter comes into action to a sufficient degree; notwithstanding this, the cultivation should be preceded by a green manuring crop (peas, castor oil, indigo, &c.), so as to supply the soil with the necessary humus, irrespective of the concurrent enrichment in nitrogen. As in all other cases, we should endeavour to encourage the thriving of the green manuring crop by a manuring with potash and phosphoric acid, for which purpose there may be used per acre :—

267 lbs. Thomas' Phosphate Powder,
,, ,, kainite.

These manurial materials are in the first place of good to the green crop, and then by this are conveyed to the sesame in the most active form. We have already suggested that the plant requires, in addition, an allowance of readily soluble nitrogen. The short period of vegetation directs attention to nitrate of soda; but inasmuch as the light calcareous soil offers conditions for nitrification, preference may, it seems to us, be given to the substance associated with soil absorption, namely, sulphate of ammonia, of which from 107 to 134 lbs. per acre should suffice.

20. EARTH NUT.

In the cultivation of the earth nut, much depends on the selection of the soil ; it must be particularly rich in lime, otherwise no fruit is borne ; failing lime in the soil in sufficient quantity, heavy lime dressings are necessary. Moreover, the ground must be open and free from weeds and

must be carefully kept in this condition, so as to ensure and assist the penetration of the young fruit in the ground.

Earth nut belongs to the pod bearers, and therefore requires no nitrogenous manuring, because it is capable of taking nitrogen from the atmospheric air, provided it finds, besides lime, sufficient potash and phosphoric acid in the soil. Potash is best applied in the form of kainite and phosphoric acid, as Thomas' Phosphate Powder, of which it is enough to use per acre about—

440 lbs. kainite,
356 ,, Thomas' Phosphate Powder.

It remains to be said that the earth nut shrub is readily eaten by cattle, and as a fodder is comparable to pea straw.

21. CASTOR OIL.

This shrub requires a mellow, deep, permeable soil; further, as regards food requirements, nitrogen is the principal material demanded, then follow phosphoric acid and potash, and in liberal supplies too, considering the rapid and vigorous development. Compost stands first for manuring the castor oil plant, and if artificial manures be employed, they may be taken in the following quantities per acre:—267 to 357 lbs. of Thomas' Phosphate Powder, a similar quantity of kainite, and 134 to 178 lbs. of sulphate of ammonia.

22. COCOA PALM.

The cocoa palm requires a great degree of moisture and precipitation; it therefore thrives particularly well near the sea, that furnishes air carrying salt as well as moisture. It can only be cultivated on dry soil when provision is made for periodical irrigation. The food requirements of the cocoa palm have only been slightly investigated; hitherto the custom has been to apply compost and wood ashes at the commencement of the rainy season. Potash and phosphoric acid unquestionably act beneficially, and if the nitrogen requirements are not covered by the irrigation or other water, then it is best to use organic nitrogenous manures, as the different oil cake meals. The most suitable mineral manures are Thomas' Phosphate Powder and kainite.

23. COTTON.

The cotton bush requires above all a permeable deep soil, of which those of a sandy loamy character are preferable; it cannot stand heavy

clays or acid humus soils. Favourable conditions are a high degree of atmospheric moisture and plenty of dew, but, on the other hand, not heavy downpours, although at the beginning of vegetation timely light rains alternating with sunshine are advantageous until the blossoming sets in; when this is wanting, artificial watering should be used as far as possible. The cotton bush demands plenty of light.

An average harvest of 300 lbs. of fibre and 654 lbs. of seed per acre takes from the soil the following nutrients :—

Nitrogen	20·8 lbs.
Phosphoric acid	6·84 ,,
Potash	9·85 ,,
Lime	1·68 ,,
Magnesia	3.67 ,,

Wohltmann gives the following numbers as the average for the long staple American cotton bush :—

	Stem.	Leaves.	Fibre.	Seed.
Ash	1·51	7·90	1·12	3·80
(Containing per cent.)				
Phosphoric acid ...	17·50	18·70	15·50	29·00
Potash	17·40	15·50	29·20	33·80
Lime...	34·80	34·50	20·40	4·70
Magnesia	3·40	1·30	4·00	18·20

Therefore, as regards mineral constituents, the cotton bush has greatest need of phosphoric acid and potash. This is also indicated in comprehensive manurial experiments conducted in Alabama, U.S.A., of which the conclusions follow :—

1. PHOSPHORIC ACID, of all foods used alone, produced the largest yields, whilst the cost was the smallest. Manuring with potash, or nitrogen alone produced considerably lower yields; that produced by the potash being about the same as that got by nitrogen, but it was cheaper.

2. Using two foods, the manuring with phosphoric acid and nitrogen gave the greatest increase, which also cost the least. The smallest harvest, at by far the greatest cost, was obtained by potash and nitrogen; potash and phosphoric acid occupying a mean position.

3. The greatest increase, which at the same time was obtained at a comparatively low cost, was obtained by the combination of the three foods, phosphoric acid, potash, and nitrogen.

In the same experiments, the effect of the different kinds of manures

on the earlier or later ripening was investigated. This question is all the more important, because the prices are as a rule better at the beginning of the season, and the gathering, according to the weather, soil, &c., continues over many months and must be done over two or three times. According to certain reports, the gathering, on the different experimental fields lasted from the latter end of August to the beginning, and in one case, even to the end of December. In this matter, too, the influence of the manuring on expediting the ripening was clearly shown, for even the application of a single manure, especially phosphoric acid, as well as the combined manuring, had considerably increased the quantity of cotton obtained in the first picking.

These results are confirmed by other manurial experiments made in Mississippi, U.S.A. A manuring with 28 lbs. of nitrogen, 110 lbs. of phosphoric acid, and 60 lbs. of potash per acre, produced the highest yield of 2,640 lbs. of fibre and seed per acre, as compared with 760 lbs. on the unmanured, therefore above 1,880 lbs. per acre more. Various changes in the composition of the different manurings also produced considerable increases, but on an average they were lower. The experimental plots are shown in Fig. XX., an unmanured plant in Fig. XXI., and a manured plant in Fig. XXII.

In the opinion of the reporter, the results obtained would have been still better, had not exceptionally bad weather ruled at the commencement of the season. Here, again, phosphoric acid stands out as the primary cause of the increase in yield, although the dressings of potash and nitrogen had so far increased the harvest, that after deducting the costs a profit of 10·5 dollars per acre remained. The soil upon which the experiments were made, would have yielded even better results had cotton seed meal been used for the nitrogenous manuring, instead of nitrate of soda. The lime manuring had no action, because it was sown in the spring; lime dressings, spread later than in December of the previous year, appear generally to exert but slight influence.

It is noteworthy, that in America manuring the cotton trees with kainite has prevented the development of the disease known as "yellow leaf blight." Moreover, we have already emphatically called attention to the fact, that well and properly nourished plants suffer less from injurious influences, than plants languishing from insufficient nourishment.

Dr. Atkinson remarks, in reference to this disease, "yellow leaf blight":—

FIG. XX. (see page 62.)

VEREIN DEUTSCH-OESTERR. THOMASPHOSPHATFABRIKEN, BERLIN.

FIG. XXI. (see page 62.)

Fig. XXII. (see page 62.)

"In many seasons the yellow leaf blight in cotton is undoubtedly of destructive action. It is to be attributed to the unsuitable nutrition of the plant, and to unfavourable physical conditions of the soil. Experiments have shown that by the use of kainite this disease would, to the greater part or entirely, be prevented, and that, besides, the yield of cotton would be increased. This has been the experience of many planters.

"The partial or total prevention of the disease was to be easily observed by comparison on all the experimental plots alluded to above, when kainite was used."

"The harvest on the kainite plots exceeded that on the unmanured, by 70 to 100 per cent., and that on all other plots where kainite was not employed, no matter what other manure was used, by an average of 40 per cent."

A. H. Clark reports in a similar strain, in reference to experiments with cotton grown on a black loam, at Hope Hall:—

"There is no doubt about the action of kainite; my previous experience coincides exactly with those of this year. I believe that it is necessary to spread 500 to 600 lbs. of kainite per acre to completely exterminate cotton disease."

The same results have been communicated from other experimental agricultural stations in America, amongst others from Dr. H. B. Butler, of the North Carolina Station, as far back as 1888.

If we quote some numbers from the above reports in connection with the manuring of the cotton plant, it must be carefully noted that they are only to furnish a general idea, and are not set forth as invariable examples to be followed implicitly. In particular cases the dressing of nitrogenous nutrient may, perhaps, be reduced, in other cases, perhaps, usefully and advantageously increased. Potash manuring must be more liberal on light than on heavy soil, and only as regards phosphoric acid do we in general abide by the numbers given.

For a complete manuring the following are about the dressings required:—

(*a*) Nitrogenous manures, per acre—

either	450	lbs. of	cotton seed cake,
or	500	,,	sesame ,,
,,	400	,,	earth nut ,,
,,	150	,,	sulphate of ammonia,
,,	200	,,	nitrate of soda.

(*b.*) Phosphatic manures, per acre—
600 lbs. of Thomas' Phosphate Powder,
(*c.*) Potash manures, per acre—
250 lbs. of chloride of potash.

Briefly summing up the result of our remarks we may say that the food requirements of the cotton bush, as regards mineral matters, extend chiefly to phosphoric acid and then to potash. Nitrogen is indispensable, as in fact we might infer in view of the large amount of vegetable matter that is produced in a short time.

24. JUTE.

This plant belongs to the linden family and requires a high degree of moisture in both soil and air. A deep soil, deeply cultivated and heavily and regularly supplied with manure, is necessary for the production of good yields. In addition to nitrogen and phosphoric acid, potash in particular must not be forgotten; it has good effect especially on soils poor in potash. For this purpose, the chlorine compounds of potash exert a good influence, so that kainite or chloride of potash should be used. For the phosphatic manuring, Thomas' Phosphate Powder stands in the foreground, and for the nitrogenous, sulphate of ammonia, assuming that the soil is not sufficiently supplied by manuring of farmyard manure or compost. It suffices to give per acre—

440 lbs. kainite or 134 lbs. chloride of potash,
356 ,, Thomas' Phosphate Powder,
134—161 ,, sulphate of ammonia.

✓25. RAMIE.

Ramie requires an open, permeable, rich soil and heavy manuring, in quantities not less and of a similar character to those mentioned for the jute plant. Ramie culture has been tried in Germany, but unfortunately without success.

26. INDIGO.

The indigo plant requires a deep, retentive but permeable soil in a high condition of fertility and cultivation. The fact that a satisfactory yield of colouring matter depends on a rapid growth and that the rapid

growth largely depends on the store of food present in the soil, manifestly points to heavy manurings.

The indigo plant belongs to the *Leguminoseæ,* therefore does not require to be manured with nitrogen, but, on the other hand, demands plenty of phosphoric acid and potash. The best phosphatic manure is undoubtedly Thomas' Phosphate Powder, particularly as it applies lime also; potash can just as well be applied as kainite, as in the concentrated salts. The following manurings per acre will prove profitable:—

356 lbs. Thomas' Phosphate Powder, and
441 ,, kainite, or 112 lbs. chloride of potash.

The continually increasing production of aniline and other dyes thrusts the natural product from the vegetable kingdom out of the field; notwithstanding this, the indigo plant will maintain a position of importance in agriculture, because as a green manure crop, it enriches the soil in nitrogen and humus.

27. SAFFLOWER

This plant does best in a mild, humus, sandy soil not deficient in lime and in a good state of cultivation. The nitrogen requirements of safflower are great, but the adequate proportion of mineral material must be allotted it, otherwise it produces leaf and branch too abundantly and at the cost of the blossom, which remains small and appears irregularly and late.

IV. RICH POTASH MANURES.—COMPLETE PERCENTAGE COMPOSITION OF STRASSFURT POTASH SALTS.

Description of Salt.	Sulphate of Potash. K_2SO_4	Chloride of Potash. KCl	Sulphate of Magnesia. $MgSO_4$	Chloride of Magnesia. $MgCl_2$	Chloride of Soda. $NaCl$	Sulphate of Lime (gypsum). $CaSO_4$	Insoluble in Water.	Water.	Pure Potash. Average.	Pure Potash. Guaranteed.
A. CRUDE SALTS. (Natural products of Mine.)	23·6									
1. Kainite	21·3	2·0	14·5	12·4	34·6	1·7	0·8	12·7	**12·8**	12·4
2. Carnallite	—	15·5	12·1	21·5	22·4	1·9	0·5	26·1	**9·8**	9·0
3. Silvinite	5·2	28·3	3·6	1·8	51·3	1·8	4·2	3·8	**20·7**	15·0
B. CONCENTRATED SALTS. (Manufactured products.)										
(*a.*) Sulphates nearly free from chlorine.										
1. Sulphate of potash ... ... (96 %	97·2	0·3	0·7	0·4	0·2	0·3	0·2	0·7	**52·7**	51·8
(90 %	90·6	1·6	2·7	1·0	1·2	0·4	0·3	2·2	**49·9**	48·6
2. Sulphate of potash and magnesia... ...	50·4	—	34·0	—	2·5	0·9	0·6	11·6	**27·2**	25·9
(*b.*) Chlorides.										
4. Chloride of potash ... ... (90 to 95 %	—	91·7	0·2	0·2	7·1	—	0·2	0·6	**57·9**	56·8
(80 ,, 85 %	—	83·5	0·4	0·3	14·5	—	0·2	1·1	**52·7**	50·5
(70 ,, 75 %	1·7	72·5	0·8	0·6	21·2	0·2	0·5	2·5	**46·6**	44·1
5. Calcined manurial salt (high percentage)...	—	44·5	22·5	4·6	12·4	2·9	5·3	7·8	**28·1**	20·0
6. ,, ,, ,, (low ,,)...	—	25·6	31·1	6·3	10·3	3·5	10·6	12·6	**16·2**	15·0
	Double Carbonate of Potash.		Carbonate of Magnesia.							
Carbonate of potash and magnesia	40·0		33·6			1·0		25·4	**18·8**	18·5

TABLES OF THE PERCENTAGE OF NUTRIENTS CONTAINED IN THE MOST IMPORTANT MANURES.

Name of Manure.	Nitrogen.	Phosphoric Acid.	Potash.	Organic matter.	Water.
I. FARMYARD MANURES (Animal Manures.)					
Fresh dung (with straw litter)					
Horse	0·58	0·28	0·53	25·4	71·3
Ox	0·34	0·16	0·40	20·3	77·5
Sheep	0·83	0·23	0·67	31·8	64·6
Pig	0.45	0·19	0·60	25.0	72·4
Ordinary F.Y.M., fresh ...	0·30	0·18	0·45	21·2	75·0
,, ,, moderately rotted	0.50	0·26	0·63	19·2	75·0
Ordinary F.Y.M., well rotted	0·58	0·30	0·50	14·5	79·0
F.Y.M. drainage, liquid manure	0·15	0·01	0·49	0·7	98·2
Domestic drainage	0·55	0·28	0·20	3·0	95·5
Poultry manure	0·63	1·54	0·85	25·5	56·0
Pigeon manure	1·76	1·78	1·00	30·8	51·9

Name of Manure.	Nitrogen.	Phosphoric Acid.	Potash.	Organic matter.	Water.
II. RICH NITROGENOUS MANURES.					
Nitrate of Soda	15·5	—	—	—	2·6
Sulphate of ammonia ...	20·5	—	—	—	4·0
Blood meal	11·8	1·2	0·7	78·4	13·4
Horn meal	10·2	5·5	—	68·5	8·5
Oil cakes :—					
Earth nut	7·6	1·3	1·5	85·6	10·4
Chinese soja bean	6·9	1·5	1·1	83·0	11·9
Cotton seed	6·2	3·1	1·6	82·2	11·2
Sesame	5·9	3·3	1·5	79·5	11·1
Cocoanut	3·7	1·3	2.0	82·0	12·7
Wool dust	5·2	1·3	0·3	56·0	10·0
III. RICH PHOSPHATIC MANURES.					
Thomas' Phosphate	—	14—21	—	—	—
Superphosphate	—	14—21	—	—	—
Double Superphosphate ...	—	44—48	—	—	—
Normal Bonemeal	—	20—21	—	—	—

V. MANURES WITH TWO OR THREE NUTRIENTS, SOME REFUSES, &C.

Name of Manure.	Nitrogen.	Phosphoric Acid.	Potash.	Organic Matter.	Water.
Phosphate of Potash	—	36—38	25—37	—	—
Nitrate of Potash	13·5	—	44·0	—	—
Dissolved Peruvian Guano	7·0	11	4·0	30·0	16·0
Fish Guano	8·5	13·8	0·3	56·2	9·8
Flesh Meal	5·8	17·4	0·3	49·1	8·0
Ash of Foliage Wood	—	3·5	10·0	—	—
Ash of Needle Wood	—	2·6	6.0	—	—
Peat Ash	—	0·2	0·2	—	—
Ash of Brown Coal	—	0.6	0·7	—	—
Ash of Coal	—	1.2	0·5	—	—